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COMPLETE SPECIFICATION

Improvements in or relating to High Voltage Supply Systems for X-Ray Tubes

We, ERNEST WILLIAM TITTERTON, of Harwell, Didcot, Berkshire, England, and HUGH GORDON VOORHIES, of 50, Trowbridge Street, Cambridge, State of Massachusetts, United States of America, British Subject and a Citizen of the United States of America respectively, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to high voltage supply systems for X-ray tubes and is specifically related to high voltage surge generators for employment in conjunction with X-ray tubes.

In the advancement of the X-ray art for commercial and research purposes, many problems have been met in attaining the X-ray intensities and energies necessary. Furthermore, difficulties have arisen in accurately predetermining the time of discharge of the X-ray tube or in other words in fixing within microseconds the occurrence of X-ray production.

For example, in following a projectile through a barrier flash X-ray technique have received widespread attention and results have been steadily improved. However, when attempts have been made to increase the voltages applied to the X-ray tubes employed, insulation and corona discharge problems immediately arose which until the present invention were not satisfactorily solved. In addition, these problems reduced others which affected timing accuracies to a great extent, even seriously impairing the value of the results obtained. It is apparent that these problems exist in connection with the X-ray examination of stationary objects as well as in connection with such examination of objects undergoing change.

In high voltage X-ray production, one of the more commonly used voltage sources is known as the Marx generator circuit. This type of circuit generally comprises a plurality of capacitors which are charged in parallel from a moderate source of direct current, the connections of the said capacitors being such that they can be discharged substantially simultaneously in series thus supplying a voltage surge; the magnitude of which is the additive result of the charge on each capacitor. More specifically, in such a circuit six capacitors for example are connected in parallel, resistors being employed to accomplish this connection. Between the positive side of one capacitor and the negative side of the following one, spark gaps are interposed so that upon arc discharge through the gaps the said capacitors are effectively connected in series and the addition of the potentials stored in each is effected. The first and last capacitors are associated in a suitable circuit with the X-ray tube, the remainder being interposed therebetween in the aforesaid manner. To initiate the high voltage surge or pulse, a pulse transformer is generally provided in suitable association with the circuit, so that upon the introduction of a so-called triggering pulse, the spark gap between the first two capacitors breaks down (due to the application of potential thereacross which is greater than the breakdown potential) and the successive or step-wise breakdown of the succeeding gaps occurs. In other words the secondary winding of the pulse transformer rises rapidly to a high potential which is applied to the first gap causing it to break down i.e. spark over, thus discharging the first condenser. The charge on the first condenser is thus added to the second and in turn causes the breakdown of the second gap.

It should be noted that in such circuits one side of the capacitors are at "ground" potential and the original or charging voltage is applied with respect to zero potential. Thus, also the surge

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voltage output is of a given magnitude with respect to this zero potential. When the magnitude is in the neighbourhood of a few hundred kilovolts, e.g., three hundred and fifty, the insulation problems are extreme and operation without detriment is doubtful.

Furthermore, when operation of such circuits is undertaken at reduced atmospheric pressures, e.g. at high altitudes, the corona phenomenon militates against timing of the surge discharge. In order to decrease the corona effect in the spark gaps (and thus reduce leakage in the circuit) the gaps were usually widened to an extent which made the spark-over breakdown haphadard in its occurrence.

It is an object of the present invention to provide a surge generator circuit for producing high voltages for X-ray tubes in which insulation problems are minimized.

It is a further object to provide such a surge generator circuit in which corona leakage is substantially eliminated.

A still further object is to provide a high voltage supply of the surge generator type for X-ray tubes, in which the time of discharge may be predetermined to fractions of a microsecond.

Another object of the present invention is the provision of an X-ray discharge circuit which is operable at extremely high voltages under reduced atmospheric pressure conditions.

The invention consists in a high voltage system for X-ray tube operation comprising a high potential surge generator having a plurality of capacitors arranged in series with spark gaps interposed therebetween to produce a high positive potential surge at the anode of an X-ray tube, a further high potential surge generator having a plurality of capacitors arranged in series with spark gaps interposed therebetween to produce a high negative potential surge at the cathode of the X-ray tube, and means for simultaneously initiating cascade discharge of the capacitors of the high potential surge generators whereby to apply high potential surges to the anode and cathode simultaneously, the means producing a voltage pulse simultaneously on a spark gap in each of the high potential surge generators whereby to initiate arc discharge breakdown of the remaining spark gaps of the high potential surge generators.

The following is a preferred embodiment of the invention reference being made to the accompanying drawing, which is a schematic diagram of a surge generator and X-ray tube.

Referring to the drawing, the system is seen to include a surge generator generically indicated by reference numeral 7, a triggering circuit generically indicated by reference numeral 8 and the X-ray tube 24 of standard two-electrode design. Included also are a source of positive d.c. potential and a source of negative d.c. potential (each with respect to ground), the said sources being of well-known design and not shown in detail, but indicated by conductors 10 and 11 respectively. Series resistors 12 and 13, as well as inductances 14 and 15, are incorporated in the charging circuits in series to prevent any surge feed-back to the respective d.c. supplies. As further protection against such feed-back, spark gaps 17 and 18 are also provided between the said charging circuits and ground, to by-pass any feed-back potentials to ground.

In place of the previously employed plurality of capacitors in the manner described above (i.e. all on one side of a potential reference point), the present invention features the establishment of a zero potential reference point 21 within the generator circuit, so that the potentials stored in the plurality of capacitors are positive or negative depending upon the position of the particular capacitor in the bank. In the embodiment shown, the ground reference point is established in the following manner: Condensers 19 and 20 are connected in series between the positive potential supply indicated by conductor 10 and the negative potential supply indicated by conductor 11 and the midpoint 21 between said condensers 19 and 20 is grounded.

Condensers 28 to 30 are disposed in the conventional Marx generator manner on one side of the series pair 19 and 20 and condensers 25 and 27 on the other, the connections being such that condensers 28 to 30 discharge in series with condenser 19 through gaps 31, 32, 35, 37 and 40 and condensers 25 and 27 discharge in series with condenser 20 through gaps 33, 34 and 39. For charging purposes, condensers 19 and 20 as a pair and the balance of the condensers in the bank are associated in parallel by resistors 41.

Triggering of the surge generator circuit is accomplished through the three-electrode gaps 42 and 43. These gaps are of a well-known design in which the triggering pulse is supplied through an electrode interposed between the main electrodes of the gaps. A triggering pulse is supplied simultaneously to electrodes 44 and 45 through the balancing divider comprising resistors 35 and 36, the said electrodes being maintained at ground potential through a respective one of said

resistors and series resistor 37 connected to ground as shown. The said pulse is fed from pulse transformer 38 and is initiated through the circuit indicated by conductors 46.

As may be seen in the drawing, the gaps 43 and 42 are disposed respectively in the positive and negative portions of the generator circuit, so that each portion is activated to breakdown simultaneously and a positive voltage surge is applied to electrode 23 of tube 24 and a negative voltage surge is applied to electrode 22 of said tube simultaneously.

More specifically, the charging voltages applied through conductors 10 and 11 are respectively thirty kilovolts positive and thirty kilovolts negative with respect to ground. Thus, condensers 25, 27, 28, 29 and 30 connected in parallel through resistors 41 are each charged at thirty kilovolts positively and thirty kilovolts negatively, the total potential difference across each being sixty kilovolts. Condenser 20, on one hand, is charged positively at thirty kilovolts and condenser 19, on the other hand, is charged negatively at thirty kilovolts.

Upon the application of a suitable input signal to pulse transformer 38 through conductors 46 e.g. of sufficient magnitude to produce a fast rising pulse having a thirty kilovolt peak value at electrodes 44 and 45, gaps 42 and 43 break down. As a consequence of the breakdown of gap 42, and the negative thirty kilovolts on condenser 19 is added to the sixty kilovolt charge on condenser 28 causing it to break down in the negative direction across gap 35 and adding the accumulated 90 kilovolts to the charge on condenser 29. The subsequent breakdown of gap 37 imposes a total charge of two hundred and ten kilovolts on condenser 30 with the result that gap 40 breaks down and this negative potential is applied to electrode 22 of tube 24. Similarly, the breakdown of gap 43, transfers the thirty kilovolt positive charge on condenser 20 to condenser 25 causing a step-wise breakdown in the positive direction, so that positive one hundred and fifty kilovolts is ultimately applied to electrode 23 of tube 24.

The potential difference across tube 24 is thus seen to be three hundred and sixty kilovolts, giving rise to a high intensity X-ray burst. It is apparent, however, that insulation problems are minor because within the condenser bank the maximum voltage with respect to ground is in the neighbourhood of two hundred kilovolts for which insulating materials and techniques are readily available. Likewise, corona discharge or leakage is avoided with minimum gap size even at reduced atmospheric pressures by providing a return path through ground point 21 and dividing in half the charging potential formerly employed which was for example, positive sixty kilovolts. As a concomitant advantage, the reduced gap dimensions required make possible accurate timing of the X-ray burst with respect to the event or object under observation to within a microsecond.

It will thus be seen that what has been described is an efficient high voltage X-ray system in which a plurality of capacitor-stored charges are applied additively in both positive and negative directions respectively to the cooperating electrodes of an X-ray tube, the surge generator circuit therefore being adapted to provide a negative voltage surge and a positive voltage surge simultaneously. Although a specific embodiment has been described, it is clear that many widely different variations will now be apparent to one skilled in the art and that no limitations should be imposed hereon except as they may appear in the appended claims.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A high voltage system for X-ray tube operation, comprising a high potential surge generator having a plurality of capacitors arranged in series with spark gaps interposed therebetween to produce a high positive potential surge at the X-ray tube anode, a further high potential surge generator having a plurality of capacitors arranged in series with spark gaps interposed therebetween to produce a high negative potential surge at the X-ray tube cathode and means for simultaneously initiating cascade discharge of the capacitors of the high potential surge generators, whereby to apply high potential surges to anode and cathode simultaneously, the means being effective to produce a voltage pulse simultaneously at a spark gap in each of the high potential surge generators, whereby to initiate arc discharge breakdown of the remaining spark gaps of such generators.

2. A high voltage system according to claim 1, wherein the means comprises an electrode interposed in the spark gap between the first and second capacitors of each of the high potential surge generators, to which electrodes a voltage pulse is applied simultaneously.

3. A high voltage system for X-ray tube operation substantially as described with reference to the drawings.

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F. FOXTON,
Agent for the Applicant.

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[This Drawing is a reproduction of the Original on a reduced scale.]